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The influence of compression garments on recovery following Marathon running

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Running Head

Compression garments and Marathon recovery

ABSTRACT

Strenuous physical activity can result in exercise induced muscle damage. The purpose of this study was to investigate the efficacy of a lower limb compression garment in accelerating recovery from a marathon run. Twenty four subjects (female n= 7, male n= 17) completed a marathon run before being assigned to a treatment group or a sham treatment group. The treatment group wore lower limb compression tights for 72 h following the marathon run, the sham treatment group received a single treatment of 15 min of sham ultrasound following the marathon run. Perceived muscle soreness, maximal voluntary isometric contraction (MVIC) and serum markers of Creatine Kinase (CK) and C-reactive protein (C-RP) were assessed before, immediately after and 24, 48 and 72 h post marathon. Perceived muscle soreness was significantly lower ($p < 0.05$) in the compression group at 24 h post marathon when compared to the sham group. There were no significant group effects for MVIC, CK and C-RP ($p > 0.05$). The use of a lower limb compression garment improved subjective perceptions of recovery, however there was no significant improvement in muscular strength, nor was there a significant attenuation in markers of exercise induced muscle damage and inflammation.

Key Words: Exercise, Muscle damage, Endurance, External pressure

INTRODUCTION

Exercise induced muscle damage (EIMD) often occurs following strenuous physical activity, particularly when the exercise has an eccentric component or is of a prolonged duration, both of these characteristics are typical of long distance running (7, 29). This phenomenon is characterised by a number of symptoms including pain, inflammation and reduced capacity of the affected muscle to produce force (10, 12). The negative symptoms associated with muscle damage are likely to affect the functional capability of the individual, resulting in a reduction in subsequent exercise performance (13). Strategies that may reduce symptoms of EIMD and enhance the recovery process are desirable, to enable the athlete to tolerate a higher training volume, frequency or intensity (8).

Prolonged endurance running is reported to cause damage to the muscle fiber and associated structures, this damage arises from several contributing processes (5). The initial damage is considered to be mechanical in nature resulting from repetitive loading on the muscle fibers (6). Following the initial mechanical damage, a secondary inflammatory process arises that is accompanied by oxidative stress. The experience of oxidative stress can further exacerbate the initial mechanical stress in a so called vicious cycle (4, 22). Elevations in markers of muscle damage and inflammation have been observed following a marathon run (24), confirming that the event causes significant ultrastructural disruption. It may therefore be possible to apply an intervention that can effectively manage the processes associated with secondary damage, either by reducing the magnitude of damage or by accelerating the recovery process.

Knowledge regarding the potential mechanisms underpinning the efficacy of compression is limited, however it is suggested that compression garments may be effective in reducing the swelling and inflammatory processes associated with muscle damage (21). It is suggested that the garment works by creating an external pressure gradient that reduces the space available for swelling to occur, thereby reducing the secondary inflammatory response (13). It has also been suggested that the use of compression can improve venous return, reduce venous pooling and enhance the removal of metabolites, this is perhaps due to an enhanced muscle pump function (3, 26). Previous research has observed reduced perceptions of muscle soreness; (3, 13), reduced concentrations of serum creatine kinase (CK) (3, 13) and a reduced inflammatory response (17, 28) with the use of compression

garments. In contrast, research has also demonstrated that compression garments have no effect on muscle soreness (2, 17), CK concentration (2, 13), lactate dehydrogenase concentration (13), and thigh girth (13). Although the physiological and biochemical effects of wearing compression garments remain poorly understood, the positive claims associated with the garments may have led to an increase in the use of compression garments in sport.

Differences in experimental design including exercise modality, duration of the application of compression and the participant's training status may explain some of the inconsistencies within the literature. Furthermore, the majority of studies have focused on power sports (14, 15, 27). Participation in endurance events such as marathon running is increasing in popularity, and the use of compression garments as training aids is also increasing (14). Thus there is a need to focus on the efficacy of compression garments on recovery in endurance based sports. To the knowledge of the authors, the use of compression following prolonged endurance running has not been examined. Accordingly the purpose of this study was to investigate the effects of wearing a commercially available, lower limb, compression garment on the recovery of strength, soreness and indices of muscle damage following a marathon run.

MATERIALS AND METHODS

Subjects

Following approval from the University's research ethics committee, in accordance with the Declaration of Helsinki, 24 recreational marathon runners (male; n=17; female: n=7), volunteered to participate in this investigation. All subjects completed a health screening questionnaire and gave written informed consent. Participant characteristics, marathon time and marathon history are presented in table 1. Subjects were asked to refrain from heavy exercise in the 48 h preceding the marathon. Subjects were also asked to refrain from using any recovery strategy, such as water immersion, NSAIDs, massage and also to refrain from consuming alcohol for the duration of the study.

Experimental Design

Subjects were required to complete a 26.2 mile self paced run in an outside environment. Subjects could select when to complete the marathon on one of three dates, the course remained the same on each date. The mean

environmental conditions for the three days were a barometric pressure of 762 ± 12 mmHg (750-771 mmHg), an air temperature of 9 ± 2°C (6-10° C), a wind speed of 16 ± 4 $km \cdot h^{-1}$ (12-20 $km \cdot h^{-1}$) and a relative humidity of 73 ± 6% (66-77%). At least 7 days before the marathon run subjects reported to the laboratory to complete a submaximal lactate profile and a maximal exercise test on a treadmill (H/P Cosmos Pulsar 4.0, H/P Cosmos Sports and Medical, Nussdorf-Traunsdein, Germany), in order to characterise the physiology of the group and establish baseline data. The submaximal lactate profile consisted of a series of stages each lasting 3 min with 30 s rest between each stage to enable the collection of a blood lactate sample, the sample was immediately analysed using an automated analyser (Biosen C-Line, EKF Diagnostic, Ebendorfer Chaussee 3, Germany). At the start of each new stage the treadmill speed was increased by 1 $km \cdot h^{-1}$, heart rate (Polar A1, Polar Electro OY, Kempele, Finland) was recorded throughout the test and a 1 min average was taken during the last minute of each stage. Ratings of perceived exertion (RPE) were assessed using the Borg scale. Subjects were asked to indicate their perception of exertion on a scale ranging from 6 (very, very light) to 20 (very, very hard) during the last 30 s of each stage. Expired air was analysed continuously using an online gas analyser (Jaeger Oxycon Pro, Jaeger Ltd, Hoechberg, Germany). The submaximal test was terminated when blood lactate concentration exceeded 4 $mmol.L^{-1}$. The participant was given 10 min rest before commencing the maximal exercise test. The test began 2 $km \cdot h^{-1}$ slower than the finishing speed of the submaximal test. Throughout the test the treadmill speed remained constant and the gradient was increased by 1% every minute. The test was terminated when the participant reached volitional exhaustion. Expired air was analysed continuously, maximal oxygen uptake ($\dot{V}O_{2max}$) was determined as the highest 30 s average. Verbal encouragement was given throughout. Subjects were matched based upon $\dot{V}O_{2max}$ and then were randomly assigned to a compression garment group (compression) or a sham ultrasound group (sham). Dependent measures included perceived muscle soreness, maximum voluntary isometric contraction (MVIC) of the knee extensors, creatine kinase (CK) and C-reactive protein (C-RP) and were assessed immediately before the marathon, within 1 h post marathon and at 24, 48 and 72 h post marathon.

Treatment Groups

The sham group received 15 min (5 min quadriceps, 5 min, hamstrings and 5 min gastrocnemius) of sham ultrasound (Combined therapy ultrasound/inferential, Shrewsbury Medical, Shropshire, UK) within 1 h of the completion of the marathon run. A water-soluble hypoallergenic ultrasound gel (Aquasonic 100 ultrasound

transmission gel, Parker Laboratories, Fairfield, USA) was applied to the leg and the ultrasound head was used to spread the gel over the skin in circular patterns. The ultrasound unit was turned off throughout the duration and the unit was obscured from view. The compression garment group were given a pair of compression tights (2XU, MA1551b men's compression tights and WA1552b women's compression tights, Melbourne, Australia), fitted according to the manufacturer's instructions. Subjects were instructed to shower and put on the garments within 1 h of the completion of the marathon run. The garments were worn for 72 h following the run, subjects were asked to wear them continuously, only removing them to shower. The degree of pressure exerted on the leg was measured using a body pressure-measuring device (Kikuhime, TT Medi Trade, Søleddet, Denmark). Pressure was measured at the medial aspect of the calf at the site of maximal girth and also at the front thigh at the midpoint between the inguinal crease and the superior aspect of the patella. Pressure measurements at each site were taken with the subject standing in the anatomical position and also during a contraction of each muscle group. Measurements were repeated 3 times with the mean value recorded.

Dependent Variables

Muscle soreness was obtained using a 200 mm visual analogue scale with 'no pain' at 0 mm and 'unbearable pain' at 200 mm (Howatson et al. 2010). Subjects stood with their feet shoulder width apart with hands on hips and were asked to perform a squat to 90° and return to standing and mark their subjective feeling of pain on the scale. MVIC was assessed using a strain gauge (MIE Medical Research Ltd., Leeds, UK). Subjects were seated on a platform, with their hip and knee joints flexed at 90°. The strain gauge was attached 2 cm above the malleoli of the left ankle. Subjects were asked to maximally extend the knee against the device for 3 s. Each participant was given 3 maximal attempts each separated by 1 min the highest of which was recorded as MVIC. Verbal encouragement was given (25).

Serum CK and C-RP were measured at each time point. Approximately 8.5 mL of blood was collected from the antecubital fossa into serum separation vacutainers (BD equipment, vacutainer systems, Plymouth, UK). Following collection the sample was immediately placed in a refrigerated centrifuge (Mikro 220R D-78532, tuttlingen, Germany) and spun at 3500 rpm, a relative centrifugal force of 3000g, for 20 minutes at 4°C to enable the separation of serum. The serum was immediately frozen at -80°C for later analysis.

Creatine kinase was analysed in duplicate using an automated clinical chemistry analyser (Modular P, Roche Diagnostics, West Sussex, UK). C-RP was analysed in duplicate from serum samples using a high sensitivity C-reactive protein ELISA kit (Kalon Biological, Guildford, UK). The absorbance of each sample was read at 405nm (Biochrom Ltd, Cambridge, UK).

Statistical Analysis

All data analyses were carried out using SPSS for Windows v 18 and values are reported as mean ± SD. An independent samples t-test was used to identify any differences in group characteristics at baseline. In order to account for inter-individual variation MVIC was expressed as a percentage change from baseline. All dependent variables were assessed using a treatment by time repeated measures analysis of variance (ANOVA). Maulchy's test of sphericity was used to check homogeneity of variance for all analysis. The Greenhouse-Geisser correction factor was used where violations of the assumption occurred. Where a significant effect was observed interaction effects were further examined using an LSD *post hoc* analysis. A significance level of $p \leq 0.05$ was applied.

RESULTS

The mean pressure of the garment exerted on the front thigh was 9.9 ± 2 mmHg in the anatomical position and 17.5 ± 3.5 mmHg during muscle contraction. The mean pressure exerted on the calf was 19.3 ± 2.6 mmHg in the anatomical position and 24.4 ± 5 mmHg during muscle contraction. There were no significant differences in $\dot{V}O_{2max}$, previous marathon history, average weekly training distance and marathon finish time between groups (Table 1). All dependent variables showed a significant time effect ($p \leq 0.004$).

Muscle soreness exhibited a significant time by group effect ($F_{(4,1)} = 30.8$, $p < 0.001$) and a significant group effect ($F_{(1,22)} = 4.451$, $p = 0.046$, with those in the compression group experiencing reduced muscle soreness (Figure 1). A *post hoc* LSD test indicated that this difference occurred at 24 h post exercise in the compression group. At this time point the sham group increased in mean soreness from 26.8 to 36.4 mm, while the compression group decreased in mean soreness from 31 to 13.9 mm.

Post marathon concentrations for CK were elevated at 24 and 48 h post exercise, with the highest values occurring at 24 h (692.1 ± 625.6 and 1022.3 ± 1439 U/L in the compression and sham group respectively). C-RP concentrations were also elevated at 24 and 48 h post marathon, with the highest values occurring at 24 h post (7.4 ± 4.6 and 10.3 ± 9.0 $mg \cdot l^{-1}$ in the compression and sham group respectively), however there was no significant difference between groups for either marker ($p \geq 0.05$; see figures 2 and 3).

Maximal voluntary isometric contraction (MVIC) was reduced immediately post marathon, returning to normal at 72h h post marathon. The largest measured decrease in MVIC occurred immediately after the marathon (82.8 ± 13.9 and 77 ± 14.8 percent of max in the compression and sham group respectively), however no significant group effect ($F_{(1,22)} = 2.256$, p = 0.124) or interaction ($F_{(4,1)} = 0.688$, p = 0.543) was observed (see figure 4).

DISCUSSION

To the authors knowledge this was the first investigation to examine the efficacy of compression garments in accelerating recovery from endurance running. It was hypothesised that the use of lower limb compression garment would enhance the recovery process following a marathon run. Those in the compression garment group experienced less muscle soreness 24 h post marathon when compared to the sham group. Despite this finding there were no significant differences between groups for MVIC, CK and C-RP, however there appears to be a trend for improved recovery of MVIC and an attenuation of CK and C-RP in the compression group.

The main finding of the present study was that the use of a lower limb compression garment significantly reduced muscle soreness 24 h after a marathon run (see Figure 1). This finding is consistent with other studies which have demonstrated that the use of compression garments results in reduced perceived muscle soreness following damaging exercise (3, 13). The experience of muscle soreness is proposed to arise from mechanical trauma to the tissue, giving rise to structural damage and an inflammatory response (11). Therefore a reduction in soreness may be related to reduced structural damage to the tissue and/or a reduced inflammatory response (3). It is suggested that the application of compression may be effective in reducing this inflammatory process, this may be because compression garments create an external pressure gradient reducing the space available for swelling, haemorrhage and haematoma (13, 21). The chain of events that occur following initial mechanical damage to the muscle fibers can result in an increased osmotic pressure within the tissue, which causes an efflux

of fluid from the capillaries into the interstitial spaces (21). The application of compression may lessen the change in osmotic pressure and consequently reduce inflammation, the circulation of inflammatory markers and the sensation of pain (21). Although this study controlled for a placebo effect by using sham ultrasound, it is possible that the finding of reduced perceived muscle soreness may be linked to the participant's belief that compression garments have a positive response on recovery.

C-Reactive protein is a marker of inflammation that has been proposed to reflect the inflammatory load on the body (30). Concentrations of C-RP were elevated following the marathon run, peaking at 24 h post marathon (see Figure 2), this is consistent with previous research (24). There was no significant group effect observed on concentrations of C-RP. Few studies investigating the use of compression garments have measured C-RP, those who have measured this marker have also found no significant effect of compression on concentrations (16). However, several have looked at mid thigh girth as an indirect measure of inflammation, one such study observed no time or group effect with mid thigh girth following the application of compression (13). This data differs from the findings of an earlier study that observed an increased thigh circumference in a contrast bathing group and a control group but no increase in thigh circumference in a compression garment group, following a bout of damaging exercise (17). Given that there were no significant reductions in the inflammatory marker CRP, the reduction of soreness is unlikely to be linked to a reduction in the inflammatory response.

Similarly to C-RP, this study observed no group effect for CK. Creatine kinase (CK), an enzyme that leaks from damaged muscle tissue into the blood stream resulting in an elevated serum concentration of CK (9), is frequently used as a marker of muscle damage. A peak increase in concentration is usually observed 24h post exercise with levels remaining elevated at 48 and 72 h post-exercise (9). The CK concentrations observed in this study follow the well established response to damaging exercise. The concentration of CK was elevated immediately after the marathon run, peaking at 24 h post exercise. The concentration of CK continued to remain elevated at 48 and 72 h post-exercise (see Figure 3). This indicates that the marathon run induced a significant amount of tissue damage. While it appears that there was a trend for higher concentrations of CK in the sham group this difference was not statistically significant. This apparent trend is consistent with the findings of previous studies that have found reduced concentrations of CK in those wearing compression garments compared to those in a control group (13, 14, 18).

Training status is a key factor that may explain why the current study has not observed a reduction in CK or C-RP when compared to previous research. Well trained individuals tend to exhibit lower concentrations of CK following a bout of damaging exercise when compared to their less trained counterparts (9). This is a reported benefit of the repeated bout effect which suggests that a bout of damaging exercise offers protection against future bouts of damaging exercise whereby the individuals experience less severe symptoms of EIMD (23). The average number of previous marathons completed by the subjects taking part in this study was 16 ± 24 suggesting that they were experienced marathon runners, it is therefore possible that the prior marathon and training history of the subjects in this study offered protection in the form of an adaptive response.

Previous studies that have indicated a lowered CK concentration following the application of compression have used club level (14) or university level (13) games players who may not be familiar with high training volumes. Howatson et al. (24) observed much higher values of CK (2814 compared to 1022 U/L in the placebo groups) and CRP (27 compared to 10 mg/L in the placebo groups) following a marathon race compared to this present study. Higher values of these markers would indicate a greater degree of muscle damage occurred, this could be related to previous marathon history as the average number of competed marathons for the subjects taking part in Howatson et al. (24) was 6 ± 8 where the average number of completed marathons for the subjects taking part in this study was 16 ± 24, indicating that the subjects in the present study were more experienced. It is possible that the potential of the garment to have a beneficial effect is attenuated with a lower magnitude of change in markers of muscle damage and inflammation. This is perhaps why, in the present study, there was a trend for reduced concentrations of CK and C-RP but no significant effect.

The use of compression garments did not improve the recovery of muscle force production following a marathon run (see Figure 4). This is consistent with the findings of others (14, 16). The effects of compression on contractile performance is unclear, it is thought that any improvement or recovery in muscle strength may be related to contractile function. The decrease in MVIC observed immediately following the marathon run may be due to both localised muscle trauma and peripheral muscle fatigue, resulting from the accumulation of H^+ ions which will inhibit excitation-contraction coupling (19). The results of this study indicate that, despite the use of compression, the recovery of voluntary muscle function was not improved. It has previously been suggested that equivocal responses in performance standards following the use of a recovery strategy may be due to training

status (17). Experienced athletes are more accustomed to the discomfort associated with high intensity exercise and are better able to reproduce performances (17).

One current argument surrounding the use of commercially available compression garments is whether they can exert enough pressure to be of any benefit (13). In contrast to this research has also suggested that garments exerting high levels of compression (23-32 mmHg) are not as effective at maintaining leg power as garments exerting low (12-15 mmHg) or medium (18-21 mmHg) pressures (1). The pressures observed within this study ranged between 9.9-24.4 mmHg. The fitting of these garments is often based upon the manufacturer's guidelines, however due to differences in body size and tissue structure the range of sizes available may not be sufficient. Whilst we measured the degree of compression exerted in this study and our compression level was similar to that achieved in other studies (3, 20), more research is needed to ascertain the optimal degree of compression in the recovery from symptoms of EIMD as well as how the degree of compression varies between individuals wearing the same size garments.

In conclusion, it would appear that the use of a lower limb compression garment, following a marathon run, results in significantly lower perceived muscle soreness at 24 h post marathon. In addition the garment had no statistically significant effect on improved recovery of muscle performance or post-exercise removal of serum markers of muscle damage and inflammation. However, despite the lack of a statistically significant effect in these markers a trend for improvement was apparent in the compression group.

Practical Application

A variety of modalities are frequently used to accelerate recovery from strenuous exercise. A number of investigations have indicated that the use of compression garments may help recovery following damaging exercise (3, 13, 21). The observation of reduced muscle soreness in this study may have implications for a number of populations, wishing to embark on exercise regimes, who are discouraged due to the experience of soreness. As such compression garments may be of use as a recovery aid when worn during the 24 h post exercise to reduce the experience of perceived muscle soreness. While this study investigated the effects of

compression in experienced, but nonetheless recreational runners, further research should look to identify whether significantly greater effects are observed in less experienced runners

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REFERENCES

1. Ali, A, Creasy, RH, and Edge. The effect of graduated compression stockings on running performance. *J Strength Cond Res* 25: 1385-1392, 2011.
2. Ali, A, Creasy, RH, and Edge, JA. Physiological effects of wearing graduated compression stockings during running. *Eur J Appl Physiol* 109: 1017-1025, 2010.
3. Ali, A, Caine, MP, and Snow, BG. Graduated compression stockings: Physiological and perceptual responses during and after exercise. *J Sports Sci* 25: 413-419, 2007.
4. Aoi, W, Naito, Y, Takanami, Y, Kawai, Y, Sakuma, K, Ichikawa, H, Yoshida, N, and Yoshikawa, T. Oxidative stress and delayed-onset muscle damage after exercise. *Free Radic Biol Med* 37: 480-487, 2004.
5. Appell, HJ, Soares, JMC, and Duarte. JAR. Exercise, muscle damage and fatigue. *Sports Med* 13:108-115, 1992.
6. Armstrong, RB. Muscle damage and endurance events. *Sports Med* 3: 370-381, 1986.
7. Armstrong, RB. Initial events in exercise – induced muscular injury. *Med Sci Sports Exerc* 22: 429-435, 1990.

8. Barnett, A. Using recovery modalities between training sessions in elite athletes. Does it help? *Sports Med* 36: 781-796, 2006.
9. Brancaccio,P, Maffulli, N, and Limongelli, FM. Creatine kinase monitoring in sport medicine. *Brit Med Bull* 81: 1-22, 2007.
10. Cleak, MJ, and Eston, RG. Muscle soreness, swelling, stiffness and strength loss after intense eccentric exercise. *Brit J Sport Med* 26: 267-271, 1992.
11. Connolly, DAJ, Sayers, SP, and McHugh MP. Treatment and prevention of delayed onset muscle soreness. *J Strength Cond Res* 17: 197-208, 2003.
12. Connolly, DAJ, Lauzon, C, Agnew, J, Dunn, M, and Reed, B. The effects of vitamin C supplementation on symptoms of delayed onset muscle soreness. *J Sport Med Phys Fit* 46: 462-467, 2006.
13. Davies, V, Thompson, KG, and Cooper, SM. The effects of compression garments on recovery. *J Strength Cond Res* 2: 1786-1794, 2009.
14. Doan, BK, Kwon, Y, Newton, RU, Shim, J, Popper, EM, Rogers, RA, Bolt, LR, Robertson, M, and Kraemer, WJ. Evaluation of a lower body compression garment. *J Sports Sci* 21: 602-610, 2003.
15. Duffield, R, and Portus, M. Comparison of three types of full body compression garments on throwing and repeat-sprint performance in cricket players. *Br J Sports Med* 41: 409-414, 2007.
16. Duffield, R, Cannon, J, and King M. The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise. *J Sci Med Sport* 13: 136-140, 2010.
17. French, DN, Thompson, KG, Garland, SW, Barnes, CA, Portas, MD, Hood, PE, and Wilkes, G. The effects of contrast bathing and compression therapy of muscular performance. *Med Sci Sports Exerc* 40: 1297-1306, 2008.
18. Gill, ND, Beaven, CM, and Cook, C. Effectiveness of post match recovery strategies in rugby players. *Br J Sports Med* 40: 260-263, 2006.
19. Green, HJ. Mechanisms of muscle fatigue in intense exercise. *J Sports Sci* 15: 247-256, 1997.
20. Kraemer, WJ, Volek, JS, Bush, JA, Gotshalk, LA, Wagner, PR, Gómez, AL, Zatsiorsky, VM, Duzrte, M, Ratamess, NA, Mazzetti, SA, and Selle, BJ. Influence of compression hosiery on physiological responses to standing fatigue in women. *Med Sci Sports Exerc* 32: 1849-1858, 2000.
21. Kraemer, WJ, French, DN, and Spiering, BA. Compression in the treatment of acute muscle injuries in sport. *Int Sportmed J* 5: 200-208, 2004.

22. Halliwell, B, and Chirico, S. Lipid peroxidation: its mechanism, measurement, and significance. *Am J Clin Nutr* 57: 715S-725S, 1993.
23. Howatson, G, and van Someren, K. The prevention and treatment of exercise induced muscle damage. *Sports Med* 38: 483-503, 2008.
24. Howatson, G, McHugh, MP, Hill, JA, Brouner, J, Jewell, AP, van Someren, KA, Shave, RE, and Howatson, SA. Influence of tart cherry juice on indices of recovery following marathon running. *Scan J Med Sci Spor* 20: 843-852, 2010.
25. Howatson, G, Hough, P, Pattison, J, Hill, JA, Blagrove, R, Glaister, M, and Thompson, KG. Trekking poles reduce exercise-induced muscle injury during mountain walking. *Med and Sci Sports Exerc* 43: 140-145, 2011.
26. Ibegbuna, V, Delis, KT, Nicolaides, AN, and Aina, O. Effect of elastic compression stockings on venous hemodynamics during walking. *J Vasc Surg* 37: 420-425, 2003.
27. Montgomery, PG, Pyne, DB, Cox, AJ, Hopkins, WG, Dorman, JC, Cook, K, and Minahan, CL. The effect of recovery strategies on physical performance and cumulative fatigue in competitive basketball. *J Sports Sci* 26: 1135-1145, 2008.
28. Trenell, MI, Rooney, KB, Sue, CM, and Thompson, CH. Compression garments and recovery from eccentric exercise: A P-MRS study. *J Sports Sci Med* 5: 106-114, 2006.
29. Vickers, A.J. (2001). Time course of muscle soreness following different types of exercise. *BMC Musculoskel Dis* 2: 1-4, 2001.
30. Yeh, ETH. CRP as a mediator of disease. *Circulation* 109: 11-14, 2004.

Table 1. Descriptive characteristics of the participants in the compression and ultrasound groups. Values are mean ± SD, N=12 per group. There were no statistically significant differences between groups for any variable.

Group	Age (yrs)	Height (cm)	Mass (kg)	VO2max ($ml \cdot kg \cdot min^{-1}$)	Finish time (h:min:s)	Previous Marathons	Weekly mileage
Compression (n = 8 male, n = 4 female)	47.7±10.8	177.8±10.2	73.3±14.1	53.8±10.2	03:46:45±00:22:30	15.6±28.8	35.3±10.5
Sham ultrasound (n = 9 male, n = 3 female)	41.1±10.5	175.3±7.0	71.6±7.3	55.6±8.4	03:39:27±00:33:10	12.7±12.1	40.9±15.2

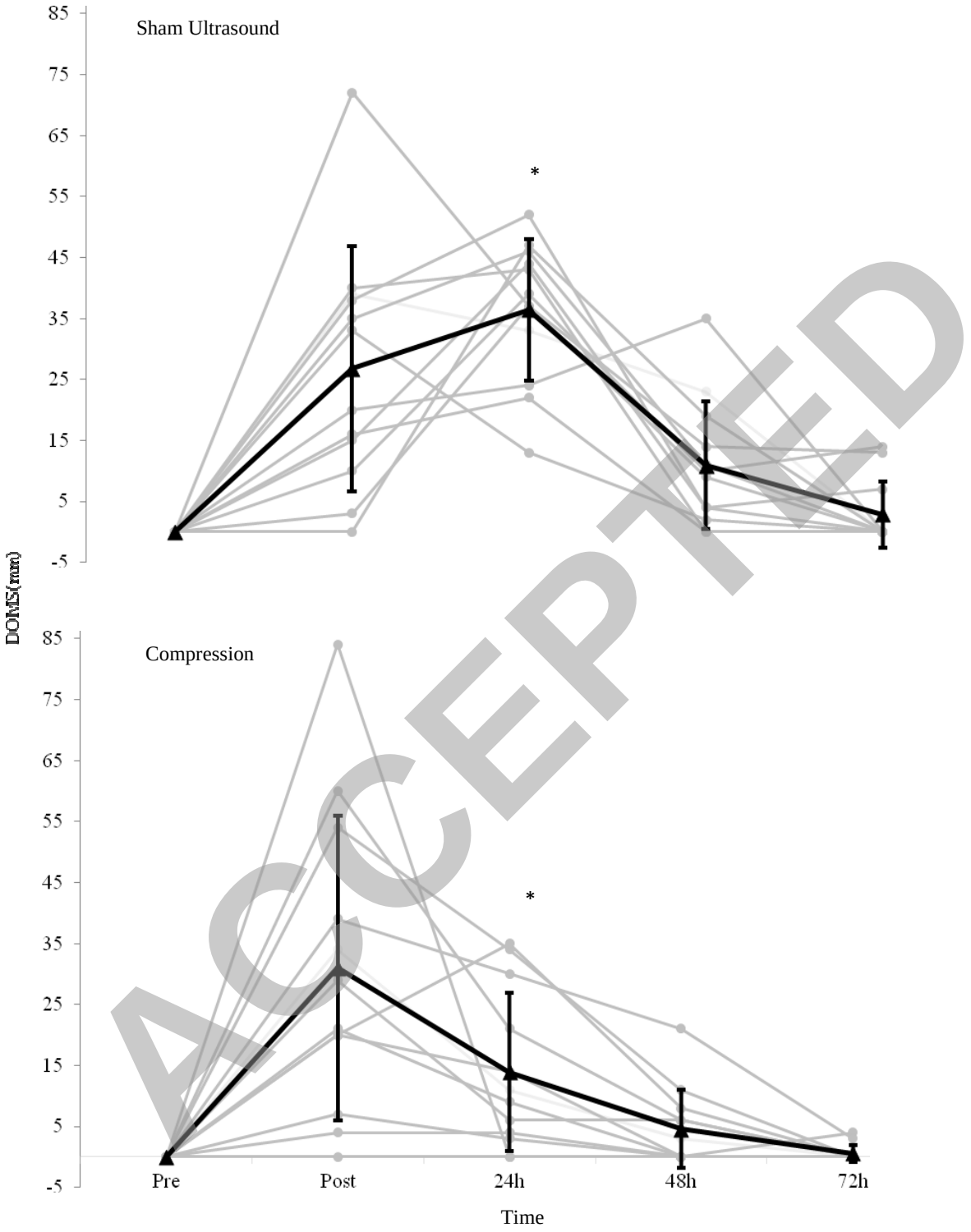

Fig. 1 Perceived rating of muscle soreness for the compression and sham groups before and after the Marathon. * significantly different from compression group (grey lines denote individual participant results, black line denotes the group mean with SD values).

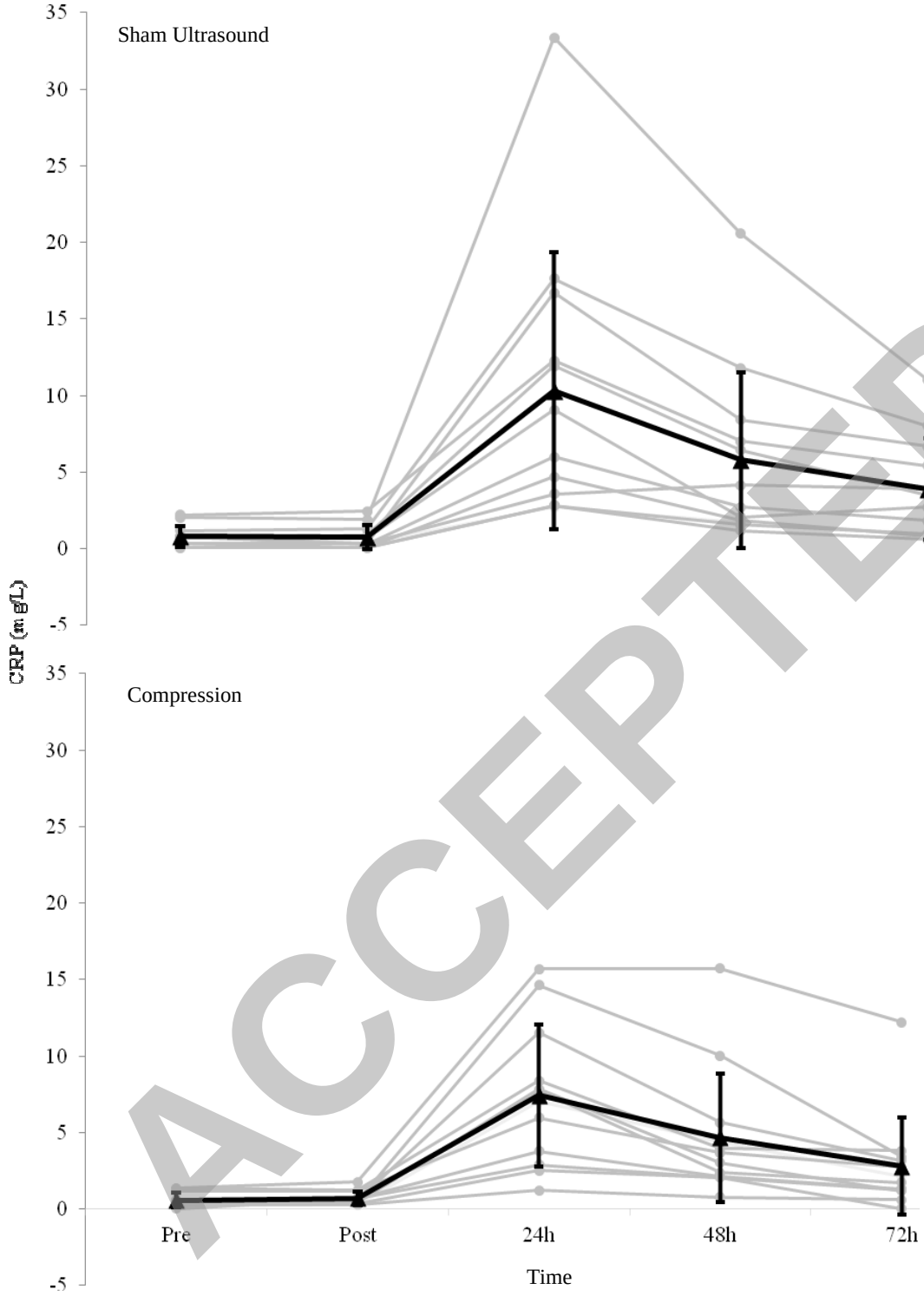

Fig. 2 Serum CRP values for the compression and sham groups before and after the Marathon. No significant differences ware observed between treatment groups (grey lines denote individual participant results, black line denotes the group mean with SD values).

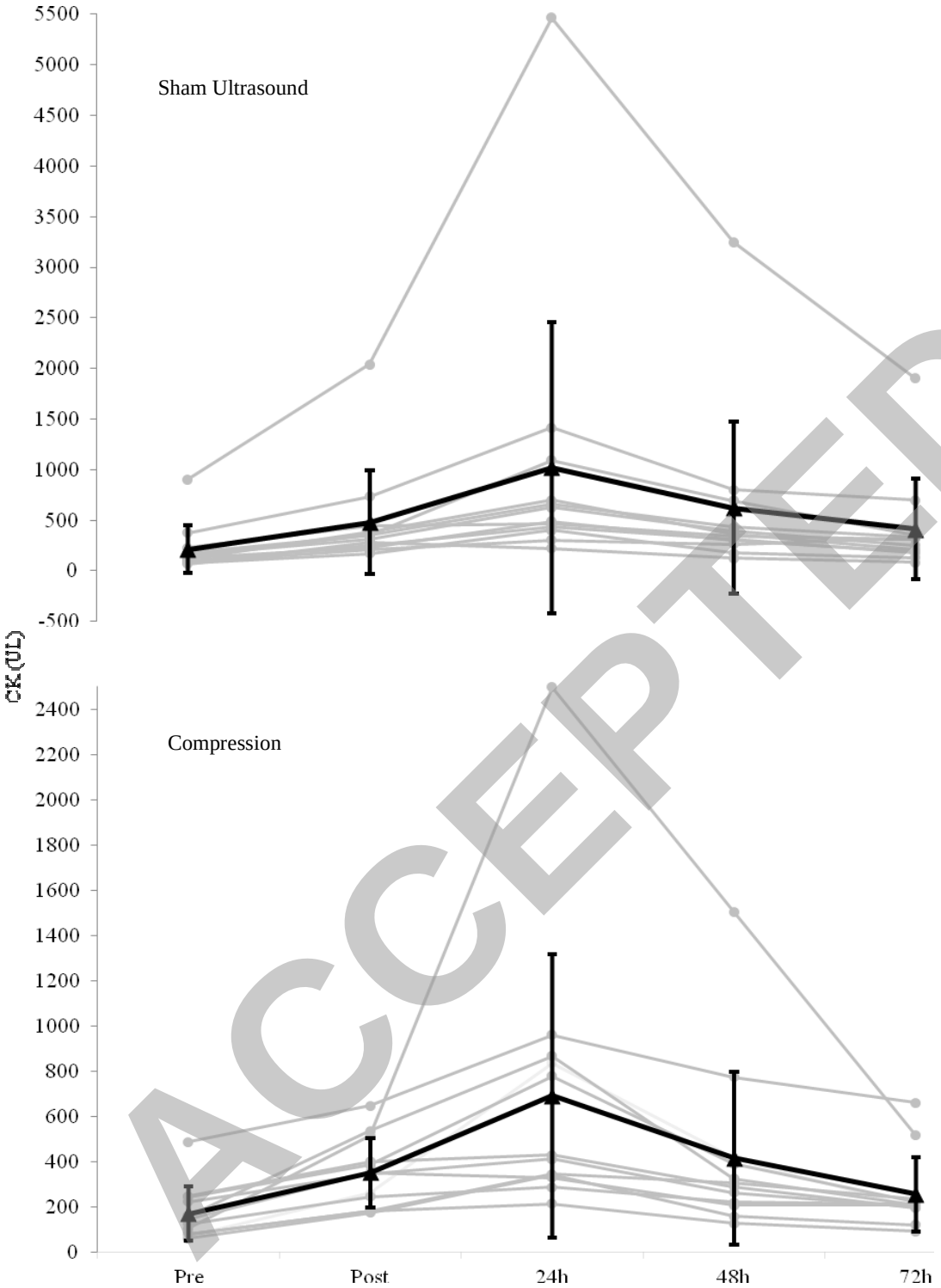

Fig. 3 Serum CK values for the compression and sham groups before and after the Marathon. No significant differences were observed between treatment groups (grey lines denote individual participant results, black line denotes the group mean with SD values).

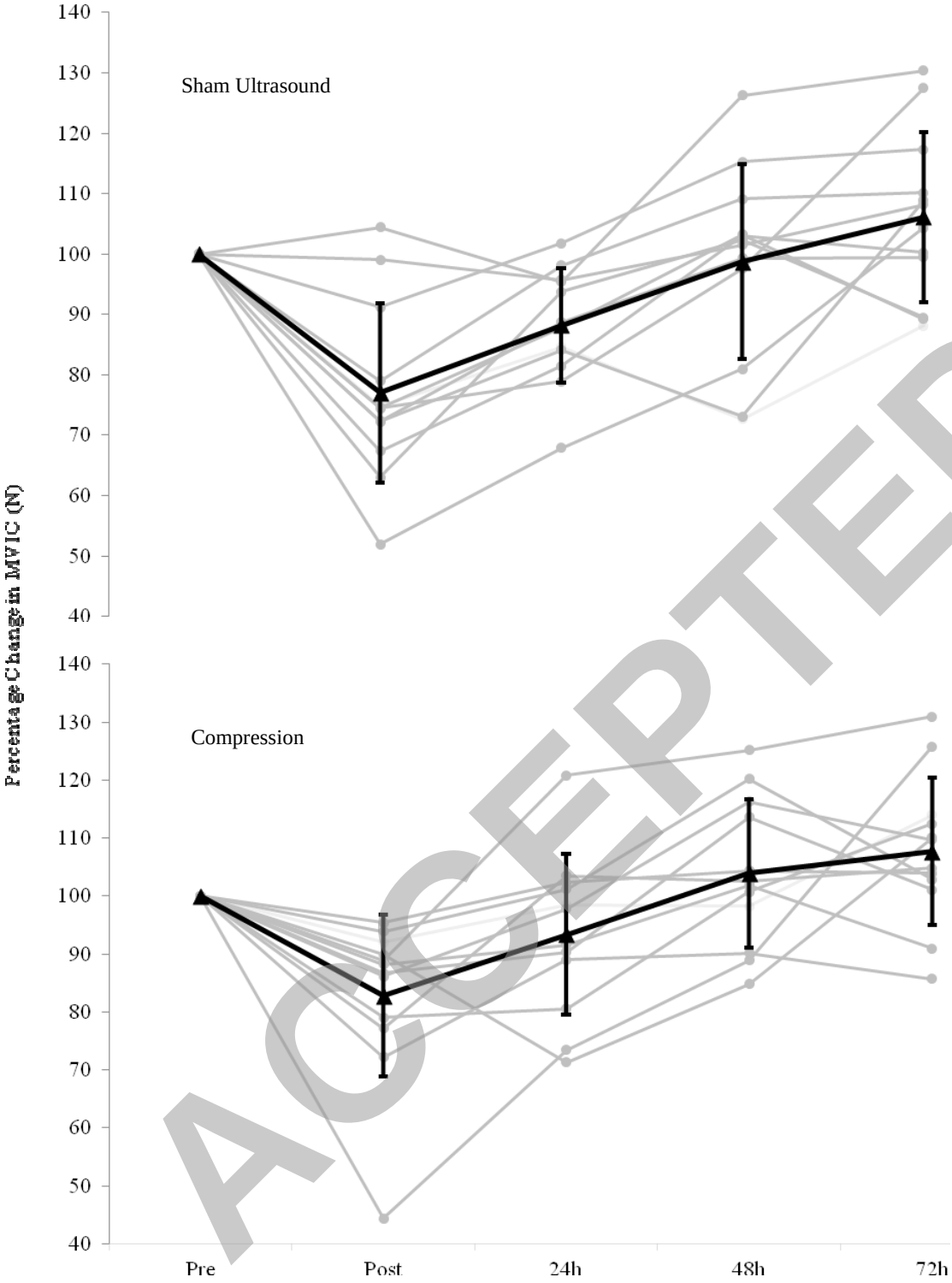

Fig. 4 Percentage change in MVIC for the compression and sham groups before and after the Marathon. No significant differences were observed between treatment groups (grey lines denote individual participant results, black line denotes the group mean with SD values).